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For: **DYNAMICALLY RECONFIGURABLE VISION SYSTEM**

Enclosed are:

- ☒ Certificate of Mailing with Express Mail Mailing Label No. **EK374791675US**
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Invention: **DYNAMICALLY RECONFIGURABLE VISION SYSTEM**

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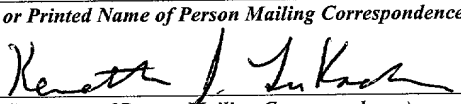
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DYNAMICALLY RECONFIGURABLE VISION SYSTEM

Description

This Application claims the benefit of priority to U.S. Provisional Application No. 60/127,698, filed April 5, 1999, which in herein incorporated by reference.

Field Of Invention

The present invention is related to a vision system (and method), and related particularly to a vision system having reconfigurable CMOS video photodetector arrays providing multiple, time-correlated, overlapping, programmable photodetector array windows. The invention is suitable for single or multiple target viewing, detection, tracking, and identification, especially where such applications are constrained by requirements of limited bandwidth, processing capability, space, weight, or power.

Background Of Invention

Vision systems for detecting, identifying, and tracking targets must acquire and process large volumes of video data in real time. Most applications requiring these tasks, however, are characterized by imagery where targets and other objects of interest occupy only a small fraction of the total scene. Hence, traditional imaging systems that employ uniform and constant spatial resolution throughout the entire field of view acquire much irrelevant information and thus burden valuable data processing and communication resources in the system. As a result, such systems are slow and do not operate at their full potential due to a flood of unimportant video information. Building vision systems with multiple cameras, several processors, high-bandwidth communication links, and specialized hardware will increase performance, but results in equipment that is complex, expensive, large, heavy, high power consuming, and prone to failures. These constraints make constant resolution vision systems difficult or impossible to use where space, speed of response, and reliability are critical considerations, for instance, in defense applications.

Humans and other vertebrates have foveal vision that allows them to concurrently perform several tasks: survey a wide field of view at a low resolution for situational awareness and detection of features or targets of interest; track moving targets with great accuracy; scan at

high resolution these multiple targets of interest; and communicate over channels with limited bandwidth (neurons) the information of interest to the computer (brain). Because high-resolution imaging is limited to the fovea, which is fixed in the center of the retina, the tracking of targets involves movement of the eyes and the head.

The vision system of the present invention operates according to a concept termed Dynamically Reconfigurable Vision, or DRV, which is inspired by the biologically proven concept of foveal vision, but is further extended for practicality in a machine vision implementation. DRV is adaptive image sensing driven by a computer or human operator's response to changing scenery. One goal of this system is to reduce the amount of irrelevant video information sensed and thus achieve more effective bandwidth and computational resource utilization than traditional vision systems. This is achieved by a system controlled by a computer or microprocessor and a photodetector array for imaging a frame of a scene through multiple independently controllable, time-correlated, overlapping photodetector array windows, which are dynamically reconfigurable in real time, and where such windows in a frame are capable of having varying resolution.

Several vision systems or imaging photodetector arrays have been developed which do not enable DRV. U.S. Patent No. 5,541,654 describes a focal plane array imaging device having sensor windowing, variable integration time, and snapshot mode. U.S. Patent No. 5,990,469 describes a control system for an image array sensors providing multiple windows. U.S. Patent No. 5,973,311 provides a pixel array imager with a high and low resolution mode. U.S. Patent No. 5,949,483 describes a multiresolution image sensor that contains an electronic shutter, can form multiple pixel windows, and possesses a multiresolution imaging circuit for averaging pixels into groups of superpixels. U.S. Patent No. 5,493,335 provides a color CCD sensor video camera that is adapted for processing images of different resolution to provide a user selectable image size. U.S. Patent No. 5,926,208 describes a reconfigurable camera with low-bandwidth transmission capability using a conventional image sensor, processor, and memory that can hold several image compression algorithms. These vision systems and sensors do not provide a reduction in the amount of irrelevant information sensed through the use of a computer-controlled system for imaging a scene through multiple independently controllable, time-correlated, overlapping sensor windows.

In a publication by NASA's Jet Propulsion Laboratory, a photodetector array circuitry is describes that performs snapshot imaging and pixel averaging, see F B. Pain and X. Zheng, Active Pixel Sensor with Photosites in Substrates, NASA Tech Brief, vol. 23, no. 10, October 1999 (from JPL New Technology Report NPO-20534). This circuitry requires the host computer to send control signals to the sensor for the extraction of the signal from each superpixel, and like the other prior art system, do not provide imaging a scene through a multiple independently controllable, time-correlated, overlapping sensor windows.

In U.S. Patent No. 5,262,871, a multiresolution image sensor is described that inputs data representing a superpixel to a computer that controls the size of that superpixel. The computer extracts video data from the photodetector array one superpixel at a time. This is time consuming and reduces bandwidth by increasing the amount of interaction between the computer and the camera. Furthermore, the values reporting the level of illumination of the superpixels generated by the system are a function of pixel size in which this value is equal to the sum of the comprising pixels. The superpixel values are normalized so that the image processing algorithms do not erroneously interpret the superpixel to represent a bright scene region. This operation requires extra time and system memory, thus slowing down the image processing. Larger pixel values also require a wider dynamic range in the video communication circuits. In addition, the photodetector array described in U.S. Patent No. 5,262,871 does not operate in a snapshot mode, so that the exposure time can be different for different pixels after the system has been reconfigured, requiring the computer to carry out additional normalization of pixel values in order to avoid a mistake in interpreting the pixel values in the context of the image. Moreover, because the pixels in this patent are exposed at different times, any motion in the field of view (due to camera and/or target motion) will introduce artifacts, such as target warping, artifacts that reduce the accuracy of the target classification. Overexposed pixels in an image will appear brighter than the properly exposed or underexposed pixels in the same image.

Other developed vision systems that use fixed geometry multiresolution have a two-dimensional photodetector array that has small size pixels in the center and larger size pixels in the periphery, closely simulating the anatomical structure of the retina. Such arrays are not reconfigurable, do not operate in a closed loop fashion with the vision processor, and require a pointing mechanism for gazing. Mechanical pointing suffers from instabilities and is slow. Further, because the topology of the array in a fixed geometry system cannot be changed on

demand, some relevant regions of the scene may not be resolved adequately, as a result sacrificing system reliability and usefulness, while the irrelevant regions may be resolved too finely, hence reducing the efficiency of system resource utilization.

In still other systems, referred to as pyramidal machine vision systems, targets are detected using low resolution; these targets are then scanned using localized high-resolution windows. However, the pixels that form the high resolution windows are not combined into superpixels directly in the pixel array, but the information from individual pixels is combined in the computer so as to mimic superpixels. These techniques require the processing of video from a uniform resolution camera to generate the pyramid data structure. As a result, the communications bandwidth and the video processing resources are not used any more efficiently than in a conventional uniform resolution camera.

Summary of the Invention

It is the principal object of the present invention to provide an improved vision system having a dynamically reconfigurable photodetector array that efficiently uses bandwidth and data processing resources.

A further object of the present invention is to provide an improved vision system that includes a video camera and a vision processor, which is located in a host computer or in the video camera.

Another object of the present invention is to provide an improved vision system having a video camera and vision processor connected in a closed loop system and interacting in a client-server relationship.

Another object of the present invention is to provide an improved vision system having a video camera and vision processor in which the vision processor sends commands specifying the imaging characteristics, such as spatial and temporal parameters, to the reconfigurable photodetector array.

Still further object of the present invention is to provide an improved vision system capable of automatically changing the resolution at which images or parts, such as windows, of images are acquired.

Another object of the present invention is to provide an improved vision system with a reconfigurable photodetector array having multiple windows: a background surveillance window

at a low resolution for detecting targets and multiple overlapping higher resolution windows generated any place targets of interest are located in the field of view, such as to resolve additional image details of the targets.

Still another object of the present invention is to provide an improved vision system having a reconfigurable photodetector array for imaging a field of view in windows which can be time-correlated and retrieved by a vision processor simultaneously through multiple output channels of the photodetector array.

A still further object of this invention is to provide a vision system in which the location, size, and shape of the windows is automatically controlled in response to the location and morphology of the target.

Yet another object of this invention is to provide an improved vision system in which the resolution of the windows can progress in multiple steps from the highest (that of a single pixel) to the lowest (that of a single superpixel encompassing the entire field of view).

Briefly described, the present invention embodies a vision system that uses closed-loop photodetector array reconfiguration for efficient utilization of bandwidth and processing resources. The system comprises a video camera and a vision processor arranged in a client-server relationship and is capable of automatically detecting, recognizing, and tracking targets of interest. To accomplish these tasks, the client vision processor determines the spatial and temporal parameters of the incoming video signal, and then passes this information to the video camera server via a window request command. On a reconfigurable photodetector array in the video camera, the system forms a low-resolution background surveillance window capable of detecting targets of interest. Superimposed on this background window in a time-correlated, non-destructive fashion are multiple higher-resolution windows corresponding to the location in the field of view of the targets. The smaller windows supporting target tracking can co-exist in a single video frame with the wide field-of-view window, permitting the detection of new targets. The system can simultaneously retrieve and process the background surveillance window as well as the foreground superimposed target windows.

Brief Description of the Drawings

The foregoing objects, features and advantages of the invention will become more apparent from a reading of the following description in connection with the accompanying drawings, in which:

FIG. 1 is a block diagram depicting the major components in accordance with the present invention;

FIG. 2 is a more detailed block diagram of the system of FIG. 1 showing a host computer, video camera, one photodetector, and an embedded controller external to the photodetector;

FIG. 3 is a block diagram similar to FIG. 2 of another embodiment of the present invention in which the host computer's capability is integrated into a processor within the video camera;

FIG. 4 is a block diagram similar to FIG. 2 of a further embodiment of the present invention in which the controller in the camera and the analog-to-digital converters are located on the same silicon substrate, i.e., chip, as the reconfigurable photodetector array;

FIG. 5 is a block diagram similar to FIG. 2 of still another embodiment of the present invention in which the reconfigurable photodetector of the previous embodiments is replaced with an infrared detector bump-bonded to a read-out integrated circuit;

FIG. 6 illustrates the software architecture of the system in accordance with the present invention; and

FIGS. 7a-c illustrate the progress of target detection and tracking by forming a wide field-of-view, low-resolution background window and higher resolution windows around the instantaneous locations of the target.

Detailed Description of the Invention

Referring to FIG. 1, a block diagram of the essential components of the DRV system **8** of the present invention is shown having two major modules: a reconfigurable video server **11** (typically embodied as a reconfigurable photodetector array within a video camera) and a vision processor **10**. These two components are connected in a closed-loop, client-server relationship. A server represents an object that is waiting to be contacted by a client object so that the server can do something for the client. In DRV system **8**, the server **11** is the reconfigurable

photodetector array **23** in the video camera **29** and the client is the vision processor **10**. The client vision processor in the computer **19** is programmed to generate commands, known as window request commands, that specify the spatial and temporal requirements (characteristics or configuration) of the video to be sensed on the reconfigurable photodetector array **23** in the video server **11**. These window request commands are transmitted to the reconfigurable photodetector array via a digital command data link **12**. Once the reconfigurable photodetector array receives a window request command, it reconfigures its resources to satisfy the demands of the window request command. After reconfiguration, the reconfigurable photodetector array acquires the video and transmits it back to the vision processor **10** via the digital video data link **13**.

To begin a client-server cycle, the client vision processor **10** in the computer **19** identifies a need for one or more video windows, each of a certain field-of-view, spatial resolution, frame rate, and spectral content. It creates a window request command and passes that to the reconfigurable photodetector **23** in the video server **11**. The array, which contains on-chip circuitry to enable spatial and temporal data reduction via overlapping windows, then reconfigures itself according to the demands of the window request command. New video frames are sensed according to the current photodetector array configuration and transmitted back to the vision processor client **10**. The reconfigurable photodetector array **23** may simultaneously transmit multiple windows, such as a background window and overlapping target windows, over multiple on-chip serial ports. The client-server loop can occur on a frame-by-frame basis, if necessary. If one or more video windows do not need to be altered in a given frame, then the DRV system **8** and reconfigurable photodetector array **23** will remember the window configuration and contents and continue to acquire and transmit those windows.

DRV system **8** is useful for applications and platforms requiring single or multiple target detection, tracking, cueing, and identification, especially when such applications are constrained by requirements for limited bandwidth, processing, space, weight, and power. Enabled by a reconfigurable photodetector array, DRV system **8** allows simultaneous acquisition and tracking of multiple targets widely separated in the field of view, without the need for smooth-pursuit mechanical tracking. Depending on the number of targets of interest, the system forms one or more high-resolution windows overlapping a low-resolution field-of-view, each high-resolution window containing a target of interest. While targets are being tracked at high resolution, the low-resolution background window remains active and continues to search for new targets over a

wide field-of-view. Templates for identifying targets of consequence can be input into the system and stored to be used for automatic selection of such targets for review and tracking at high resolution. In addition, targets can be initially detected based on their movement, contrast, shape, and, with appropriate video photodetector arrays, heat emission or color. DRV system **8** is described below in more detail in FIGS. 2-6.

Referring to FIG. 2, one embodiment of system **8** is shown having a host computer **19** and a digital video camera **29**. The host computer **19** includes the vision processor **10** that acts as a client and generates the window request command and processes received digital video. Vision processor **10** may be either a single processor or a multi-processor network that is connected to an arbitrary computer peripheral bus **18** and the random access memory (RAM) **14**. Also communicating with the peripheral bus **18** is a video display **16** and one or more input/output devices **17** that may include, but are not limited to, a mouse, joystick, keyboard, track ball, keypad, and custom user console. A bi-directional digital interface **15** is responsible for transmitting window request commands from the vision processor **10** to the video camera **29** via the digital command data link **12**. The digital interface **15** may be any wirebound or wireless interface capable of transmitting the window request commands and receiving digital video.

The digital video camera **29** contains a bi-directional digital interface **20** that is compatible with the host computer interface **15**. The video camera interface **20** may also have multiple ports for networking multiple video cameras **29** over additional wirebound or wireless digital channels **31**. The digital interface **20** connects directly to an embedded processor **21**. This processor is responsible for handling the digital communication protocol among the host computer, video camera, and any additional networked video cameras. The processor **21** shares a bi-directional data link with one or more programmable logic devices **22** that act as a controller for the reconfigurable CMOS photodetector array **23**. The controller **22** also interfaces to programmable voltage supplies **27**, analog-to-digital converters **24**, as well as FIFOs and registers **25** that pipeline multiple video channels into one digital video data bus **32**. The video bus **32** delivers digital video to either the processor **21** or to a bank of random access memories **26**. Optics **28** are necessary to focus light onto the reconfigurable array **23**. Additional accessories **30** may be embedded in the camera without detracting from the spirit of this invention. These may include, but are not limited to, an embedded web server, microphones, serial ports, or a global positioning system receiver. The accessories **30** may share a link with

the camera digital interface **20** or the embedded processor **21**.

The closed-loop operation and data flow of the preferred embodiment in FIG. 2 are described in the following. First, the vision processor **10** creates an initial window request command to start the video acquisition process. A likely initial command would be for a wide field-of-view, low-resolution window that occupies the entire reconfigurable photodetector array **23**. The vision processor may use this initial window for detecting target motion or target contrast against a background. The vision processor **10** then dispatches the window request via the host computer peripheral bus **18** to the host digital interface **15**. Here the window request is repackaged according to the communication protocol being employed and transmitted via the digital command data link **12**. Next, the window request command is received by the video camera digital interface **20** and conveyed to the embedded processor **21**. Here, the window request command is extracted from its digital transmission protocol and transmitted to the embedded system controller **22** via a simple serial data link. Within the controller **22**, the window request command is translated into a series of digital vectors for controlling the multiple, programmable windows on the reconfigurable photodetector array **23**, the photodetector array bias voltages **27**, multi-channel video digitization **24**, and video multiplexing **25**. The photodetector array **23** views a scene through optics **28**. The controller **22** sends spatial vectors to the photodetector array directing the photodetector array **23** to output a two-dimensional array of pixels (or pixel signals) imaging the scene in a frame combining the pixels into one or more windows which may be overlapping. The photodetector array **23** may as described in earlier cited, JPL New Technology Report NPO-20534 and U.S. Patent No. 5,949,483, and in the NASA Technology Brief from JPL New Technology Report NPO-20555 ~~(Snap Shotmode Control Pixel Integration),~~ which are herein incorporated by reference.

The reconfigurable photodetector array **23** is capable of changing the resolution of the array by automatically varying the number of individual pixels that constitute a single image resolving element, called a superpixel, having any number of individual pixels from a single pixel to all the pixels in the photodetector array. Said windows are areas of any size, shape, and frame rate within the boundaries of the photodetector array that contain a plurality of said superpixels all having the same resolution. The resolution of the image in each window is controlled by pixel averaging, or other pixel reduction techniques, to achieve the desired low to high resolution. Reconfiguration of imaging characteristics, such as integration time and frame

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*1 also JPL New Technology Report NPO-20866 (Real-time Reconfigurable CMOS Imager with Variable High-Fidelity Spatial Sampling with Multiple Windows)

*2 A High Speed CMOS Imager with Motion Artifact Suppression and Anti-Blooming

rate, and the size, resolution, location, and overlap of windows in a frame, is controlled in accordance with each window request command. The host computer can direct the resolution of one or more photodetector array windows to be increased or decreased in multiple steps, and each window maintains a consistent resolution regardless of the resolution of overlapping foreground or background windows.

Furthermore, the photodetector array includes electronic circuitry simulating the function of an optical shutter such that when open the electronic shutter allows all the pixels to respond to the light entering the video camera and when closed not to respond to the light from the scene.

In response to signals from the controller **22**, the reconfigurable photodetector array **23** outputs one or more channels of analog video to a multi-channel analog-to-digital converter **24**. Multiple channels of digitized video are then transferred to a FIFO and registers **25** where additional control bits are added by the controller **22** and the digital video is multiplexed onto a single data bus **32**. From the data bus **32** the video can go to a memory bank **26** where the video pixels will be stored as a contiguous block and can be accessed as appropriate by the embedded processor **21**. The digital video on the data bus **32** can also be delivered directly to the embedded processor **21** where it is packetized into a transmission protocol and delivered directly to the digital interface **20**. From the interface **20** the digital video is transmitted outside the camera over a digital video data link **13** to the host computer interface **15**, where the video is received and delivered to a memory bank **14**. From memory **14**, the vision processor **10** can access the stored digital video and process it. Processing may take the form of image enhancement; compression; target detection, tracking, cueing, and recognition; or other algorithms designed to complete a mission involving surveillance or multi-target detection and tracking. After processing on the vision processor **10**, the processed video is transferred over the peripheral bus **18** to a video display **16** for graphical display and possible user interaction via one or more of various input/output devices **17**. Finally, the vision processor **10** creates a new window request command as a result of video processing results and/or user interaction. Thus begins a new cycle of the closed-loop DRV system.

Referring to FIG. 3, another embodiment of a DRV system **8** is shown without a host computer in which a video camera **29a** is provided having corresponding components to video camera **29** of FIG 2, except for processor **21** and controller **22**. This embodiment is suitable for embedded applications, such as remote autonomous surveillance and targeting. In such a system,

the embedded processor **21** doubles as the client vision processor **10**. The embedded controller **22**, in combination with the reconfigurable photodetector array **23**, acts as the video server. Thus, the basic client-server model of FIG. 1 is satisfied. The memory bank **26** can be increased in size in this embodiment to hold sequences of video images, intermediate target detection, tracking algorithm data, and executable code. The data links **12**, **13**, and **31** are used to transmit very low bandwidth control, status, and target information to and from a base station, the reconfigurable video camera **29a**, and other similar video cameras **29a**. For example, the base station may be a remote computer system.

Another embodiment of system **8** is shown in FIG. 4 in which a video camera **29b** is provided having corresponding components to video camera **29** or **29a** of FIGS. 2 and 3, respectively, except for the embedded controller **22** and the analog-to-digital converter **24** which have been integrated onto the reconfigurable photodetector array **23**. This embodiment forms an application-specific DRV system for platforms that are highly constrained according to size, weight, and/or power.

FIG. 5 shows still another embodiment of system **8** having an video camera **29c** having corresponding components to video camera **29** or **29a** of FIGS. 2 and 3, respectively, except for reconfigurable photodetector array **23** being replaced by an infrared detector **33** bump-bonded to a CMOS read-out integrated circuit **34** that implements and enables the present invention. The read-out integrated circuit also contains on-chip analog-to-digital converters for digitizing multiple video streams from the detector **33**. Although this embodiment depicts an embedded controller **22**, this controller **22** can be integrated onto the read-out integrated circuit (ROIC) **34** in the same manner as the embodiment described in FIG. 4.

The software architecture of system **8** for providing dynamically reconfigurable vision is shown in FIG. 6. First, a Detection and Tracking Application (DTA) **35** generates a request for an initial video surveillance window that covers the entire photodetector field-of-view but possesses a low resolution. The DTA **35** passes this request to the window request command generator **36**. Here, the request is packaged into a window request command **37** and sent to the video server 11. First, the window request command must pass through a software driver **38,** which controls digital message transmission via the digital command data link **12**. At the other end of the data link, another software driver **39** receives the transmitted window request command and passes it onto a window request command interpreter **40**. This software module

40 takes apart the window request command message and handles communication via a serial command interface **41** with reconfigurable photodetector array's control firmware **42**. Within the firmware control module **42**, the window request command is translated into a sequence of digital control vectors and signals **43** that are used to manage the circuitry on the reconfigurable photodetector **23**, the video digitization process, and the movement of digital video **44** through the video camera **29**. The digital video **44** is next transferred to a video packaging node **45** where it is bundled into a software data structure and transferred to an output driver **46** that handles transmission via the video data link **13**. At the opposite end of this data link, another software driver **47** receives the digital video and passes it across a bus **48** to the DTA **35**. In the DTA video processing algorithms perform all or some of target detection, tracking, cueing, identification, recognition, and classification. Based upon the digital video content, the DTA **35** makes a determination as to what spatial, temporal, and spectral parameters the next video windows should possess. This information is then passed on to the window request command generator **36**, and the cycle begins again. The DTA **35** may also possess the ability to display the digital video and create a graphical user interface for interaction with a human operator.

FIGS. 7a-7c illustrates schematically the process of target detection, tracking, and identification using first a low resolution window that occupies the entire frame (FIG. 7a), followed by the formation of multiple higher resolution windows around each target (FIG. 7b), and, finally, by multiple small, very high resolution windows each containing a target (FIG. 7c). At this point, the targets can be automatically identified by a human operator or by automatically comparing them to stored templates. This sequence also illustrates the overlapping nature of the multi-resolution windows of the present invention; FIG. 7b and 7c depicts the higher resolution target interrogation windows being formed that non-destructively overlap the lower-resolution background surveillance window. Thus, the resolution in windows are gradually increased as the size of windows is decreased to facilitate the resolution of detail in target or target(s) and the accuracy of tracking of the target(s). All of the windows are time-correlated on the reconfigurable photodetector array **23** and can be read from it simultaneously through multiple output ports.

System **8** enables Dynamically Reconfigurable Vision (DRV) to provide adaptive image sensing driven by a computer or human operator's response to changing scenery, such that the amount of irrelevant video information sensed is reduced. Thus, system **8** has more effective

bandwidth and computational resource utilization than traditional vision systems, whereby a scene may be imaged in time-correlated, overlapping windows, with frame-by-frame local (window) resolution selection. In real time, the system adaptively adjusts to changing scene dynamics, thus reducing the amount of irrelevant data read off the reconfigurable photodetector array and making better use of the available communication and data processing resources. Furthermore, the reconfigurable photodetector array can enable multiple windows of varying resolution that can overlap in a non-destructive fashion and can be retrieved from the reconfigurable photodetector array simultaneously. Several technologies make this possible, including the use of one or more reconfigurable photodetector arrays that detect visible, infrared, or ultraviolet radiation. In the case of visible radiation, the reconfigurable photodetector array can use a complementary metal-oxide semiconductor (CMOS) photodetector array and on-chip (monolithic) spatial and temporal data reduction circuitry. For infrared detection, the array may be an infrared photodetector array, where a CMOS readout integrated circuit (ROIC) is bonded to each photodetector array, and there is circuitry on the ROIC that implements spatial and temporal data reduction. The host computer **19** in the embodiment of FIG. 2 and the processor **21** in the embodiments of FIGS. 3, 4, and 5, control photodetector array **23** or ROIC **34** via controller **22** to provide multiple independently controllable, time-correlated, frequently overlapping windows for a frame of an image on the photodetector array **23** or ROIC **34** that can be reconfigured according to size, location, resolution, integration time, and frame rate. The multiple photodetector array windows can be dynamically reconfigurable in real time on a frame-by-frame basis, on the order of microseconds per reconfiguration. The client-server software architecture of system **8** enables the vision processor client to pass window request command messages to the reconfigurable photodetector array server, which in turn delivers the requested video windows back to the client processor. The system **8** is capable of simultaneous reconfiguration, integration, processing, and readout of multiple video windows.

One feature of system **8** is that the host computer **19** (or processor **21**) issues only one brief high-level configuration command per frame to the photodetector array, as opposed to prior art systems which require a host computer to send multiple control signals to the reconfigurable photodetector array for the extraction of the signal from each superpixel, i.e., averaged pixel set, imaged. Further, by using an electronic shutter on the pixel array, all pixels are exposed simultaneously irrespective of their position, size, and illumination history. The pixel averaging

technique in the reconfigurable photodetector array does not require pixel value normalization by the computer, reducing processing and communication requirements to the host computer.

Another feature is that the video server **11** allows frame-by-frame software control of on-chip photodetector array windowing, pixel resolution, and pixel averaging functions. Low-bandwidth video transmission is provided to the host computer by the reconfigurable photodetector array in the camera having spatial and temporal data reduction means, under control by the host, to reduce the amount of image data communicated to the host in comparison with prior art vision system. Thus, based upon the scene content, a processor or human operator can issue window request commands on a per-frame basis to control the spatial, temporal, and spectral characteristics of windows in a frame. The topology of the windows of the reconfigurable photodetector array can be modified frame-by-frame in an appropriate response to the instantaneous conditions in the scene being imaged, thereby enabling multiple targets in a scene to be extracted such as for tracking, in which the host computer can determine signatures of target objects. This is facilitated by the ability of the system to control the resolution of the photodetector array windows automatically in selected windowed locations of the frame corresponding to the instantaneous location of the image of a target or other targets without changing the resolution of the remainder parts, i.e., windows, of the frame.

It is to be understood that the preceding descriptions are illustrative only and that changes may be made in the dynamically reconfigurable vision system, subject of this invention, in its components, materials and elements, as well as in all other aspects of this invention discussed herein without departing from the scope of the invention as defined in the claims.

CLAIMS

1. A vision system for imaging a scene using a dynamically reconfigurable photodetector array comprising:

a video camera having at least one reconfigurable photodetector array capable of imaging a scene;

means for controlling characteristics of imaging by said photodetector array; and

a computer system for receiving signals from said photodetector array representing the scene imaged by said photodetector array and sending signals to said controlling means to configure the characteristics of imaging by said photodetector.

2. The system according to Claim 1 wherein said photodetector array provides signals representing a frame with one or more windows having pixels.

3. The system according to Claim 2 wherein said photodetector array further comprises means for controlling the resolution of the pixels in each of said windows.

4. The system according to Claim 2 wherein one or more of said windows overlap in said frame.

5. The system according to Claim 1 further comprising a client-server interface between said computer system and said controlling means.

6. The system according to Claim 1 wherein said controlling means represents a controller located on said photodetector array.

7. The system according to Claim 1 in which said controlling means represents a logic device separate from said photodetector array..

8. The system according to Claim 1 wherein said computer system is integrated into said video camera.

9. The system according to Claim 1 wherein said computer system is separate from said video camera.

10. The system according to Claim 1 wherein said computer system sends signals to said controlling means representing window request commands that contain information used to dynamically reconfigure one or more of said photodetector arrays imaging characteristics.

11. The system according to Claim 1 wherein said characteristics represent spatial and temporal parameters.

12. The system according to Claim 1 wherein said photodetector array contains a plurality of individual pixels that have fixed dimensions.

13. The system according to Claim 1 wherein said photodetector array represents a complementary metal oxide semiconductor photodetector array responsive to radiation in the visible spectral range.

14. The system according to Claim 1 wherein said photodetector array represents a device responsive to infrared wavelengths.

15. The system according to Claim 1 wherein said photodetector array is bonded to a complementary metal oxide semiconductor read-out integrated circuit.

16. The system according to Claim 1 wherein said computer system and said video camera are part of a closed-loop interactive system.

17. The system according to Claim 2 wherein said computer system is capable of analyzing video imagery for target objects and determining the necessary position, size, shape, resolution, and frame rate of multiple, overlapping windows within said vision system's field of view.

18. The system according to Claim 2 wherein said computer system is capable of determining the spectral signatures of said target objects.

19. The system according to Claim 2 wherein said computer system further comprises a user interface enabling a human operator to analyze video imagery for target objects and determine the necessary position, size, shape, resolution, frame rate, and spectral content of multiple windows within said vision system's field of view.

20. The system according to Claim 1 wherein said computer system further comprises means for generating a window request command to said video camera identifying said characteristics.

21. The system according to Claim 2 wherein said computer system further comprises means for generating a window request command to said video camera identifying said characteristics, in which said characteristics represents any of position, size, shape, resolution, frame rate, and spectral content of multiple windows.

22. A method of tracking objects in a scene comprising a frame of windows comprising the steps of:

locating at least one object to be tracked in one of said windows in a low resolution;

forming one or more windows having said object in a high resolution; and

Identifying said object in said windows of said high resolution.

23. The method according to Claim 22 wherein a plurality of said windows of high resolution are formed corresponding to the number of targets in said scene.

DYNAMICALLY RECONFIGURABLE VISION SYSTEM

Abstract

A closed-loop vision system is disclosed that utilizes a concept known as Dynamically Reconfigurable Vision (DRV), which is adaptive image sensing driven by a computer or human operator's response to changing scenery. The system reduces the amount of irrelevant video information sensed and thus achieves more effective bandwidth and computational resource utilization, as compared to traditional vision systems. One or more reconfigurable photodetector arrays sensitive to either visible, infrared or ultraviolet radiation are present in the DRV system. These photodetector arrays feature on-chip means for spatial and temporal data reduction implemented through multiple independently controllable, time-correlated, frequently overlapping windows on the photodetector array that may be programmed according to their size, location, resolution, integration time, and frame rate. All photodetector array windows are dynamically reconfigurable in real time on a frame-by-frame basis. Furthermore, a DRV system is constructed in a client-server architecture in which a vision processor client passes window request command messages to the reconfigurable photodetector array server, which in turn delivers the requested video back to the client processor. The ability to simultaneously reconfigure, integrate, process, and readout multiple photodetector array video windows is an important characteristic of the DRV system.

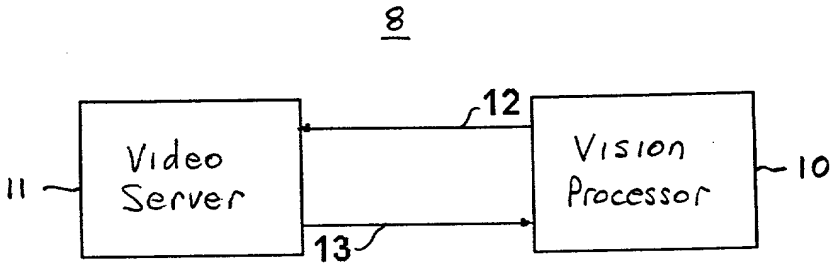
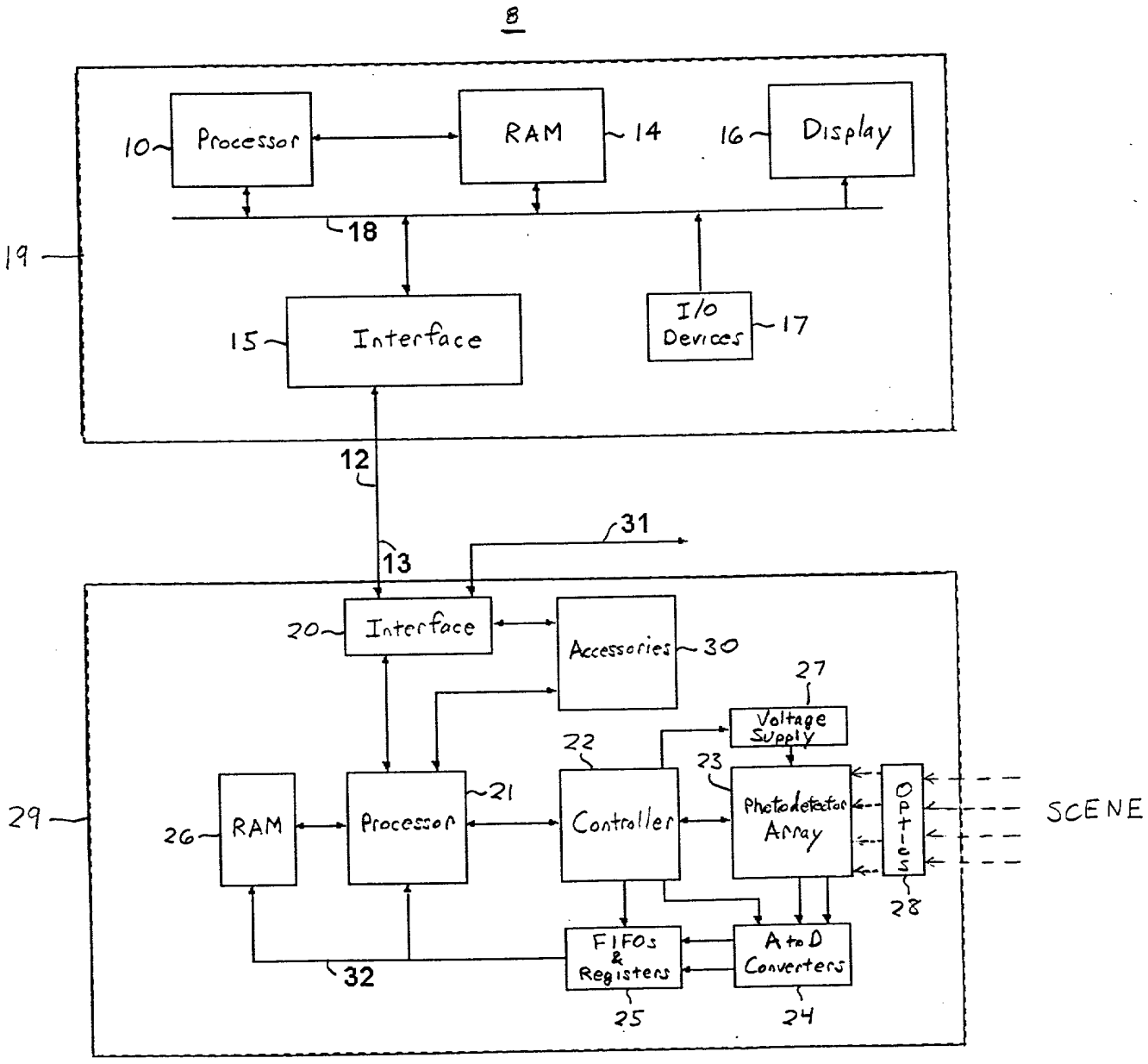

8
12
Video Server
11
Vision Processor
10
13

FIG. 1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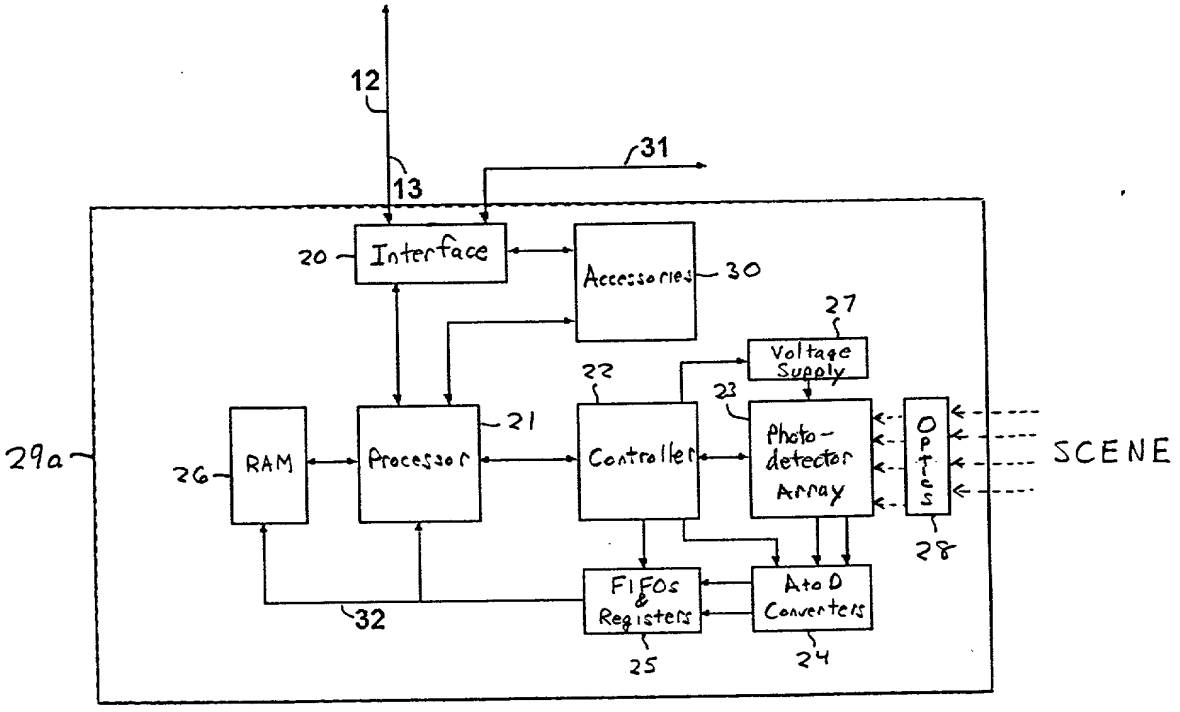
Processor
10
RAM
14
Display
16
18
19
Interface
15
I/O Devices
17
12
13
31
Interface
20
Accessories
30
27
Voltage Supply
22
23
29
RAM
26
Processor
21
Controller
Photodetector Array
Optics
28
SCENE
FIFOs & Registers
25
A to D Converters
24
32

FIG. 2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13
31
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Interface
Accessories
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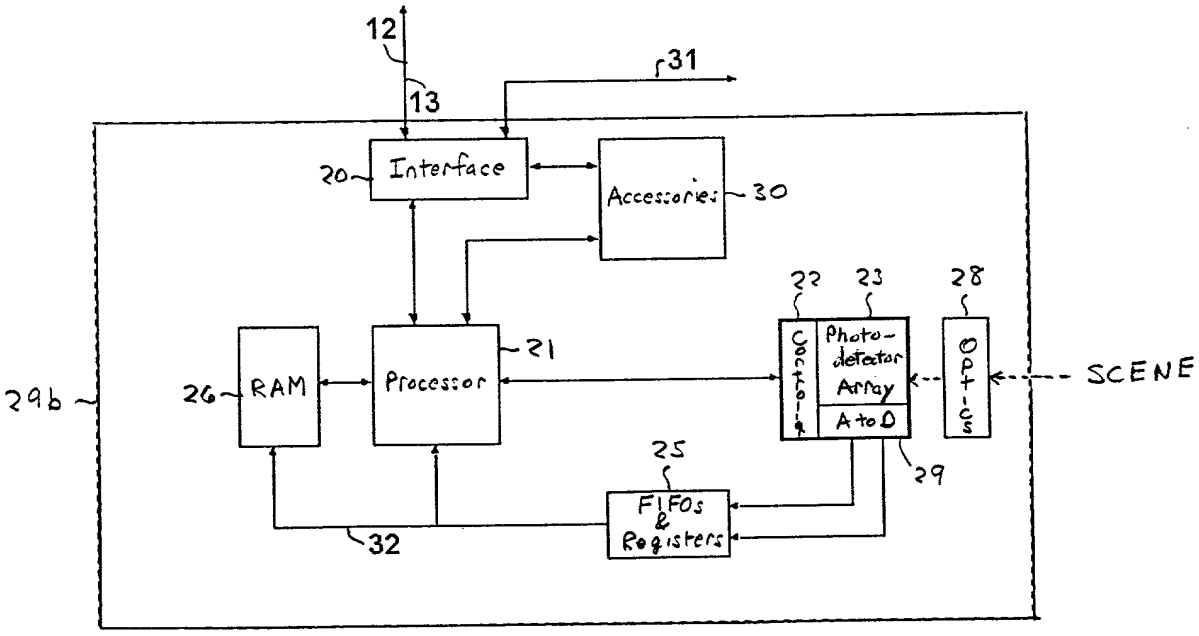
Voltage Supply
22
23
Photo-detector Array
Optics
28
SCENE
29a
26
RAM
Processor
21
Controller
FIFOs & Registers
25
A to D Converters
24
32

FIG. 3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13
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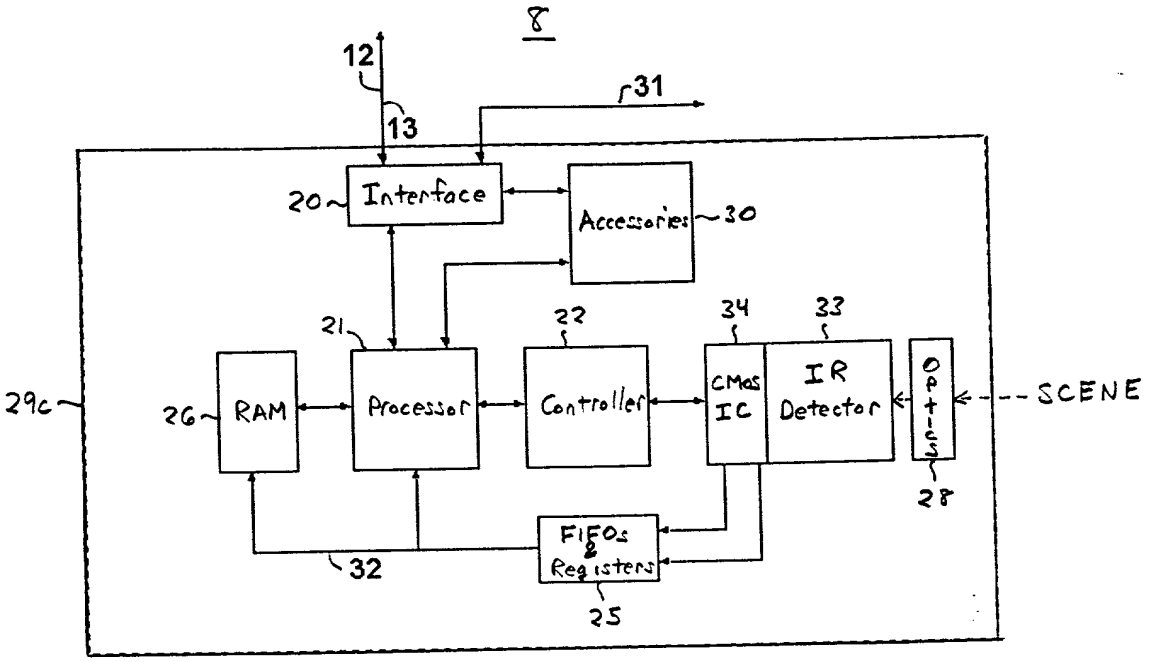
20
Interface
Accessories
30
22
23
28
Photo-detector Array
A to D
Optics
SCENE
29b
26
RAM
Processor
21
25
FIFOs & Registers
29
32

FIG. 4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Interface
Accessories
30
21
22
34
33
29c
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RAM
Processor
Controller
CMos IC
IR Detector
Optics
SCENE
28
FIFOs & Registers
32
25

FIG. 5

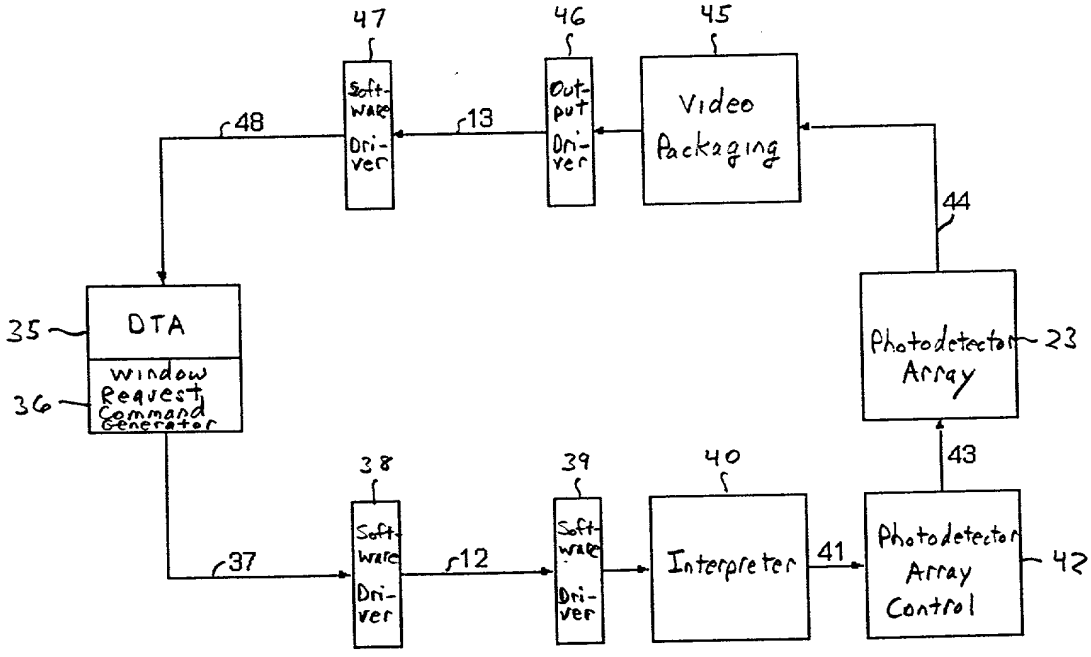
47
46
45
Soft-ware Dri-ver
Out-put Dri-ver
Video Packaging
48
13
44
35
DTA
36
Window Request Command Generator
Photodetector Array
23
38
39
40
43
Soft-ware Dri-ver
Soft-ware Dri-ver
Interpreter
41
Photodetector Array Control
42
37
12

FIG. 6

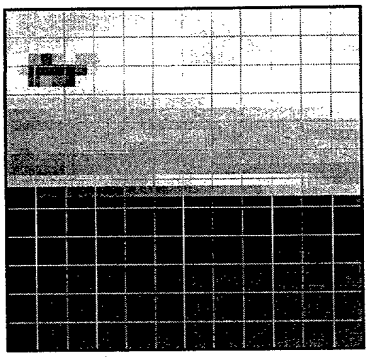

FIG. 7(a)

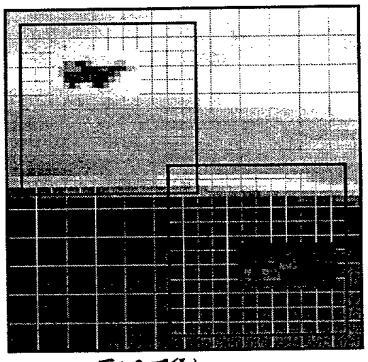

FIG. 7(b)

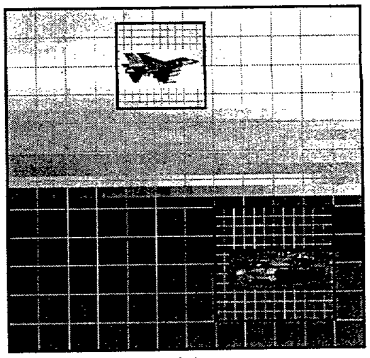

FIG. 7(c)

Docket No.
ML-0495CV

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

DYNAMICALLY RECONFIGURABLE VISION SYSTEM

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International Application Number _____

and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	☐
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	☐
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

60/127,698	April 5, 1999
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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Third inventor's signature
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Fourth inventor's signature

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Full name of fifth inventor, if any

Fifth inventor's signature

Date

Residence

Citizenship

Post Office Address

Full name of sixth inventor, if any

Sixth inventor's signature

Date

Residence

Citizenship

Post Office Address